Observing the Effects of Diets High in Sugar on the Concentration of Trace Elements in Teeth

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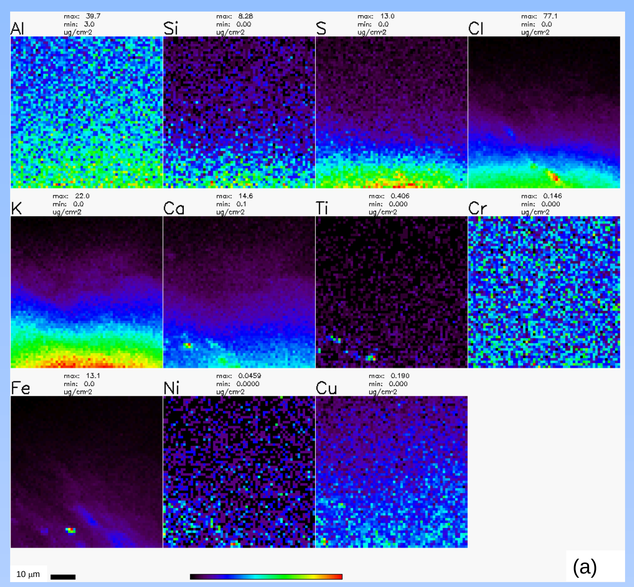
Abstract

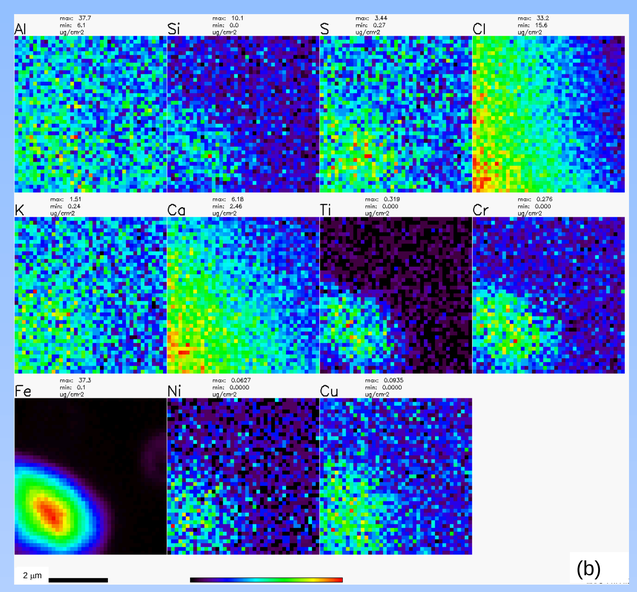
"Diseases of Civilization" is a term used to describe various non-contagious and non-genetic illnesses that can occur due to a mismatch between our anciently-derived human genome, which has been little changed over the past 200,000 years or so, and diets and lifestyles commonly associated with cultural industrialization. One particularly well-known problem is the high sugar content of diets in the industrialized world. Diets high in sugar have been linked to a number of different human illnesses such as obesity, Type 2 Diabetes, and tooth decay.

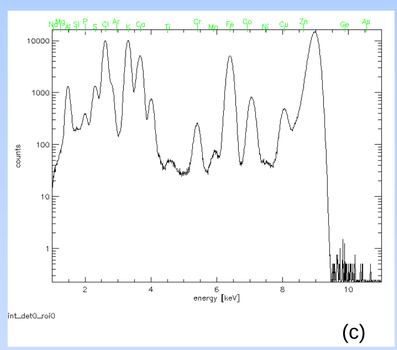
In this experiment, we used synchrotron radiation to determine the effect of a diet high in sugar on the concentration of trace elements in rat teeth. The concentration of various trace elements in teeth has been linked to environmental or dietary exposure, and can have an effect on the physical and chemical properties of teeth. There is a well-established causal link between a diet high in sugar and tooth decay, and some evidence to show that dental caries (tooth decay) have an impact on the chemical composition of teeth.

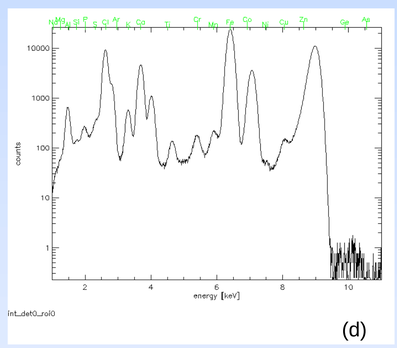
Our results for this experiment were mixed. Only data from one of the samples was viable for analysis, so making a comparison of chemical composition of hard dental tissues due to diet was not possible. However, our evidence shows that x-ray fluorescence can be a powerful tool to assay the environment and behavior of an animal subject.

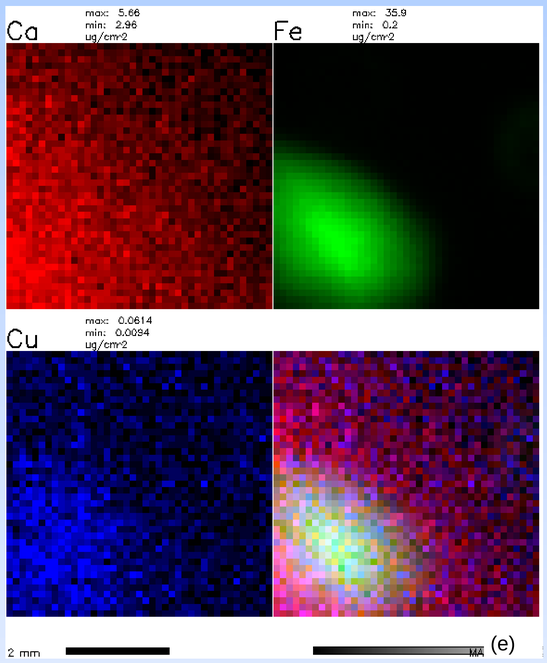
Results











Summary of Results

a. Lower resolution elemental map of tooth enamel from Group C

b. Higher resolution elemental map of tooth enamel from Group C.

c. Integrated line spectra from the lower-resolution elemental maps.

d. Integrated line spectra from the lower-resolution elemental maps.

e. RBG Co-Location from high resolution elemental map.

Observations

Due to technical issues, only one of our two samples was able to be analyzed. Therefore, a comparison of the chemical composition of hard dental tissues was not possible in this experiment.

Tooth enamel is composed of the mineral hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), which results in the presence of calcium in our results.

Through the elemental maps of our data, we observed that co-location occurred between calcium, chlorine, potassium, and sulfur (Image a).

The strongest co-location was evident between calcium and chlorine, possibly due to specimen exposure to chlorine in their local environment such as the use of sodium hypochlorite for cage hygiene during the original study. This may result in a higher proportion of chlorapatite ($Ca_{10}(PO_4)_6Cl_2$) to hydroxyapatite in the tooth enamel.

The element-specific spatial maps also reveal co-location between several transition metals: iron, chromium, and copper (Image e). We believe that this is due to a small shard of metal from the environment embedded into the tooth of the animal specimen.

The RGB co-location image at the left shows that the concentration of iron and copper is co-located in the tooth sample, whereas the concentration of calcium is evenly distributed. This further shows evidence that the iron present in the sample likely comes from a particle in the environment, rather than a source of iron evenly distributed throughout the enamel of the tooth.

Motivation & Future Studies

One of the main motivations for this project was to introduce a novel technique to discover evidence of nutritional history, residential mobility, and exposure to heavy metals that could potentially be retrieved from archaeological and even fossil teeth. Previous studies in this area use techniques that provide only aggregate chemical information from the sample.[1] The sensitivity and the spatial resolution of the hard x-ray nanoprobe at the APS may provide a unique way to potentially discover new information that could lead to insights regarding the effects of changing lifestyles and environment on human physiology.

Possible future studies may include a comparison of samples to determine the effect of a high sugar diet on the chemical make-up of dental hard tissues, specifically the higher than expected concentration of chlorine in our samples. In addition, this technique may also be used to make a comparison of the effects of diet and environment on enamel chemistry between different subgroups and potentially across multiple historical eras.

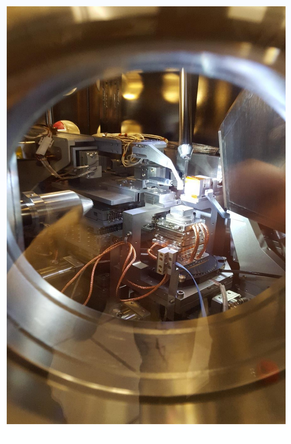
Experimental Methods

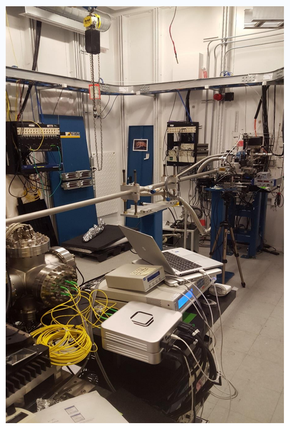
The samples used were part of a previous study that looked at the effect of a high sugar diet on behavior.[3] The specimens analyzed were fed a controlled diet. Group 1 was the control group, fed ad libitum chow; Group 2 was fed 24-h high fructose corn syrup (HFCS) as well as chow; Group 3 was fed 12-h HFCS and ad libitum chow; and Group 4 was fed 12-h sucrose and ad libitum chow. All of the subjects were fed their respective diets for 8 weeks. The sample analyzed in this study was a part of Group C.

The image above is a Cone Beam Computed Tomographic (CBCT) x-ray scan of the sample analyzed during the experiment. During this experiment, the molars of the rodent (as indicated by the yellow arrow in the CBCT scan above) were analyzed.

Samples were analyzed using the Center for Nanoscale Materials Hard X-ray Nanoprobe instrument, which operates on Sector ID-26 at the Advanced Photon Source. The hard x-ray nanoprobe has many unique capabilities, including having a high x-ray flux as well as a 30 nm spatial resolution that allows for trace element analysis at small length scales.

X-ray fluorescence allows for the creation of element specific maps at the nanoscale to determine not only the presence of an element, but also where it is physically located in the sample. These measurements were used to create the spatial maps above.





References & Citations

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